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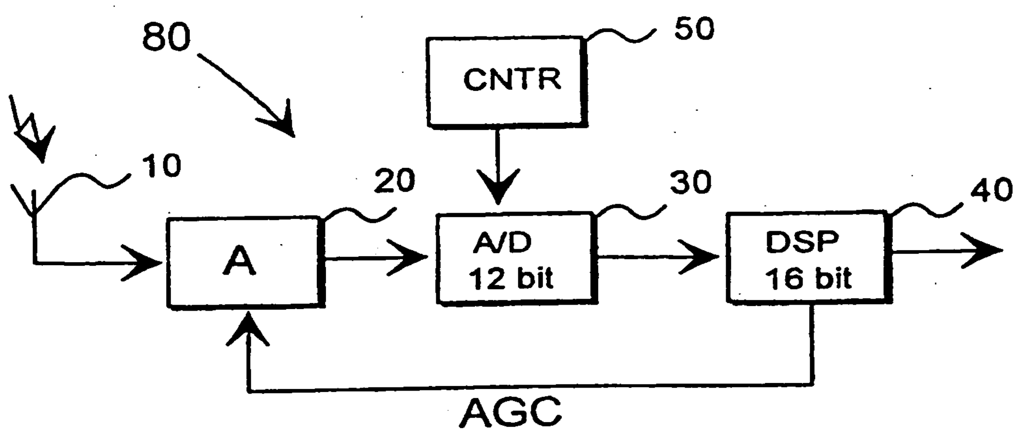

(57) Abstract

The invention relates to a reception method and a receiver (80) used in a TDMA radio system for receiving signals placed in timeslots. The receiver comprises amplifier means (20) for changing the level of a received signal by means of automatic gain control, and converter means (30) for taking samples of the signal placed in the timeslot, the converter means (30) using the samples to convert the signal into digital. The receiver also comprises control means (50) for adjusting the levels of the signal samples generated by the converter means (30) to optimal by means of automatic gain control by the control means (50) using the levels of the signal samples generated at the start of the timeslot to adjust the levels of the signal samples generated in the same timeslot later than the signal samples generated at the start of the timeslot.

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RECEPTION METHOD AND RECEIVER

FIELD OF THE INVENTION

The invention relates to a reception method used in a receiver of a TDMA radio system for receiving signals placed in timeslots and for changing the level of the received signal by automatic gain control, and for taking samples of a signal placed in a timeslot for converting the signal into digital.

BACKGROUND OF THE INVENTION

A typical feature of a radio network environment is that a signal does not propagate directly between a user and a base station. Depending on the characteristics of the environment, the signal propagates from a transmitter to a receiver via a plurality of paths of different lengths. This kind of multipath propagation takes place even if the base station and the mobile station are within sight of one another. Multipath propagation is mainly due to reflections from surrounding surfaces. Signals propagating on different paths have transit delays of different lengths and arrive at the receiver in different phases. The subscriber terminal can be e.g. a mobile phone, whereby the movement of the subscriber terminal causes different reflections. The relative movement of the subscriber terminal also causes a frequency change of the size of the Doppler shift in the signal with respect to the nominal frequency of the signal.

In a cellular network, users are located at random with respect to the base station and each other. Between the base station and the subscriber terminal, the attenuation of a signal modulated to a carrier is represented by transmission link attenuation, which increases at least in quadrature as the distance increases.

Fading occurs if the multipath components propagating to the receiver on different paths are summed up in the receiver. Carriers transmitted by subscriber terminals close to the base station propagate fairly directly to the base station. A carrier transmitted far away from the base station, in turn, may be reflected, causing the carrier to propagate to the base station on several different paths. Carrier reflections cause different problems, such as rotary phase errors in the signal received by the receiver. Problems arise in signal reception when subscriber stations are in motion, and signal frequencies change due to the Doppler shift.

Propagation loss causes weakening in a transmitted signal, whereby signals transmitted at the same transmission level have different levels

when arriving at the receiver. Different interfering signals generated by signal reflection may be summed up to an information signal in opposite phases, causing further attenuation in the information signal. Different obstacles may attenuate the signal the more the longer the distance between the transmitter and the receiver. If the signal attenuates enough, the connection between the subscriber terminal and the base station may be disconnected or the connection cannot be established at all in the first place.

In radio systems, connections can be established by signals at different frequencies. Signals can also be transmitted by interleaving them suitably into timeslots. A signal propagated a long way on the radio path has typically required a lot of amplification in the receiver. A signal which has a short way from the transmitter to the receiver has typically been amplified only slightly in the receiver.

In other words, the receiver of the base station requires as wide a dynamic range as possible to be able to receive signals with widely varying levels. The size of the dynamic range of the receiver is affected to a particularly large extent by the dynamics of the A/D converter used in the receiver. If the level of a received signal exceeds the maximum limit of the dynamic range of the A/D converter, the converter only gives a reading corresponding to the maximum limit. The maximum reading of the converter could be e.g. 0x7fff. The converter can display the maximum reading all the time during which the level of the input signal remains above the maximum limit of the dynamic range of the converter. When the input signal of the receiver exceeds the maximum limit of the dynamic range of the A/D converter, the input signal loses information.

Variation in the level of a received signal during a timeslot has been a major source of problems in the operation of receivers. Problems have arisen e.g. in TETRA systems (TETRA = Terrestrial Trunked Radio), in which the typical duration of a timeslot is 14.1 ms. The dynamic range of an A/D converter has to be wide, since signal level may have varied substantially during a period equal to a timeslot. In prior art receivers, problems have been reduced by setting the level of a signal to be received slightly before the start of a timeslot to optimal in view of the A/D converter by means of AGC circuits (AGC = Automatic Gain Control).

However, widening the dynamics of an A/D converter in such a manner that a converter having a relatively narrow dynamic range could be

used in a receiver which receives signals at highly varying levels has become a problem. The use of converters with higher dynamics has been the easiest manner to increase the dynamics of a receiver. However, the problem in an A/D converter having high dynamics is its relatively high acquisition price. In addition, problems have arisen in adapting the A/D converter to signal processing parts.

BRIEF DESCRIPTION OF THE INVENTION

It is an object of the invention to provide a reception method and a receiver for implementing the method to solve the above problems.

This is achieved by a method of the type described in the introduction, characterized by adjusting the levels of the generated signal samples to optimal by means of automatic gain control by using the levels of the signal samples generated at the start of the timeslot to adjust the levels of signal samples that are generated in the same timeslot later than the signal samples generated at the start of the timeslot.

The invention also relates to a receiver used in a TDMA radio system for receiving signals placed in timeslots, comprising amplifier means for changing the level of a received signal by means of automatic gain control, and converter means for taking samples of a signal placed in a timeslot, the converter means using the samples to convert the signal into digital.

The receiver of the invention is characterized by comprising control means for adjusting the levels of the signal samples generated by the converter means to optimal by means of automatic gain control by the control means using the levels of the signal samples generated at the start of the timeslot to adjust the levels of signal samples that are generated in the same timeslot later than the signal samples generated at the start of the timeslot.

The preferred embodiments of the invention are disclosed in the dependent claims.

The invention is based on combining the gain information obtained from automatic gain control and the sample obtained from the converter means, allowing prevention of rapid changes in signal levels.

The reception method and receiver of the invention provide several advantages. The reception method allows widening of the dynamic range of a receiver. The method adjusts a signal at several points of a timeslot, allowing prevention of transients generated by signal discontinuities. The receiver may

also use the method to generate a digital signal with a low bit error ratio.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail in association with preferred embodiments with reference to the attached drawings, in which

Figure 1 schematically shows a receiver of the invention,

Figure 2 shows widening of the dynamic range of a receiver,

Figure 3 illustrates the use of automatic gain control,

Figure 4 shows the combined use of automatic gain control and a sample signal,

Figure 5 is a flow diagram clarifying generation of a calculated sample signal to be used in a receiver, and

Figure 6 shows a radio system which uses the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 schematically shows a receiver 80 of the invention. The figure only shows the parts of a receiver which are relevant to the invention. The receiver 80 comprises an antenna 10, amplifier means 20, converter means 30 and signal processor means 40. From the radio path the receiver receives by its antenna 10 a signal which is applied to the amplifier means 20 after reception. The amplifier means 20 amplify or attenuate the received signal. After amplification or attenuation, the signal is applied to the converter means 30. In practice, the converter means are implemented by an A/D converter. Once the analog signal has been converted into a digital signal, the digital signal is applied to the processor means 40, implemented by e.g. a digital signal processor.

In the solution of the figure, the antenna 10 receives signals which are placed in timeslots and applied via the amplifier means 20 to the converter means 30. The converter means 30 take samples of the signal and use them to generate a digital signal. Sampling may take place at the frequency of e.g. 162 kHz. If the receiver receives symbols placed in timeslots, then one symbol may required e.g. nine samples. The receiver according to the figure uses automatic gain control, partly implemented by feedback from the processor means 40 to the amplifier means 20.

The receiver further comprises control means 50 connected to the

converter means 30 in the solution of the figure. The control means 50 adjust the level of the signal samples generated by the converter means 30 to optimal by automatic gain control. Automatic gain control allows the processor means 40 to receive sample signals generated from the same symbol, the sample signals being substantially at the same signal level. The advantageous use of signal samples and automatic gain control enables widening of the dynamic range of the receiver.

Figure 2 shows widening of the dynamic range of a receiver. If the converter means 30 are e.g. 12-bit and the processor means 40 e.g. 16-bit, then the converter means 30 typically determine the size of the dynamic range of the receiver. However, the figure shows that the method of the invention allows the dynamic range of a receiver to be widened substantially to the size of the dynamic range of the processor means 40.

As stated above, the converter means 30 take samples of the received signal. The signal samples which are in the same timeslot and which are used to generate the digital signal, are generated at slightly different times. The more samples are taken of a signal, the better and more exactly the digital signal corresponds to the signal being sampled. However, in practice, samples are only taken to a degree which ensures a sufficiently high probability of the converted signal being restored to digital form. Samples are taken evenly at different points of a signal, whereby the entire signal placed in a timeslot will be gone through.

The converter means 50 use the levels of the signal samples generated by the converter means 30 to adjust the levels of signal samples to be generated later. More exactly, the control means 50 use the samples generated at the start of the timeslot to adjust the levels of signal samples to be generated later in the same timeslot. The control means 50 preferably adjust the levels of signal samples to be generated later from the signal of the same timeslot on the basis of the level of the signal sample generated first in the timeslot.

Figure 3 clarifies the use of automatic gain control. The figure shows automatic gain control at different points of a timeslot. As can be seen from the figure, the level of a received signal is adjusted at the start of the timeslot. Adjustment at the start of a timeslot is what is known as rapid AGC, preferably carried out only once. Rapid AGC is not necessarily very exact, but it serves to fix the dynamic range. After rapid control, what is known as slow

AGC is used in the timeslot to adjust the signal level up or down e.g. one decibel at the time.

Figure 4 shows the combined use of automatic gain control and a sample signal. The figure shows that after rapid control at the start of the timeslot, the AGC data is combined with the sample signal generated by the converter means 30.

In the following, the operation of the amplifier shown in Figure 1 will be described in greater detail. The control means 50 of the amplifier are connected to the amplifier means 20 by means of feedback. When required, the control means 50 adjust the amplification coefficient used in signal amplification so that the levels of the signal samples increase. The control means 50 also set certain limit levels for the level of the sample signal. If the level of the sample generated later is lower than the pre-set level, the amplifier means 20 use the first samples of the signal to increase the levels of the signals to be generated later. Samples generated later are preferably changed on the basis of the first sample generated from the signal.

If the level of a sample generated later exceeds the pre-set level, the control means 50 further use the level of the signal sample generated at the start of the timeslot to reduce the levels of samples to be generated later. If the level of the sample signal is within the pre-set limit, the control means 50 generate, on the basis of the sample signal and the amplification coefficient used in automatic gain control, a calculated sample, which is used as the actual signal sample. However, the control means 50 may adjust the amplification coefficient used in signal amplification on the basis of something else than signal level.

The control means 50 generate the calculated sample by multiplying the sample signal and the reciprocal of the amplification coefficient used in automatic gain control. However, the calculated sample can be generated in another manner than by multiplication. Figure 5 shows a flow diagram clarifying generation of the calculated sample. The calculated sample generated by the control means 50 is used as the actual signal sample, which is further used in generating receiver algorithms. The flow diagram shows that the level of the signal sample is first compared with an upper limit. If the level exceeds the upper limit, amplification is decreased. The control means 50 also store an AGC value, whereby it can be used also for the following sample.

If the level of the signal sample does not exceed the upper limit, the

level is compared with a lower limit. If the signal level is below the lower limit, amplification is increased. The control means 50 also store the AGC value being currently used, whereby it can be used for the following sample. If the level of the sample signal is between the set upper and lower limit, the control means 50 generate a calculated sample. The control means 50 also compensate for the effects of the amplification coefficient used in automatic gain control to prevent the generation of signal samples having widely varying levels. In practice this means that if the amplification of the amplifier means 20 is increased e.g. 3 dB, the samples generated by the converter means 30 have to be decreased similarly by an attenuation coefficient producing 3-dB attenuation.

Figure 6 shows a radio system using the method of the invention. The radio system described is preferably a system in which each signal is placed in a relatively long timeslot. A radio system of the above type is e.g. the TETRA system, in which the duration of a timeslot is so long that the channel has time to change substantially during the timeslot. The radio system shown in the figure comprises a base station 100, a number of subscriber terminals 200 and a base station controller 300. The figure shows that the receiver 80 of the invention may be located e.g. in the base station 100 or in the subscriber terminal 200.

Although the invention has been described above with reference to the example according to the attached drawings, it is obvious that the invention is not restricted thereto, but can be modified in a variety of ways within the scope of the inventive idea disclosed in the attached claims.

CLAIMS

1. A reception method used in a receiver (80) of a TDMA radio system for receiving signals placed in timeslots and for changing the level of the received signal by automatic gain control, and for taking samples of a signal placed in a timeslot for converting the signal into digital, **characterized** by

adjusting the levels of the generated signal samples to optimal by means of automatic gain control

by using the levels of the signal samples generated at the start of the timeslot to adjust the levels of signal samples generated in the same timeslot later than the signal samples generated at the start of the timeslot.

2. A method as claimed in claim 1, **characterized** by using the level of the signal sample generated at the start of the timeslot to adjust the levels of signal samples to be generated later in the same timeslot on the basis.

3. A method as claimed in claim 1, **characterized** by using the level of the signal sample generated at the start of the timeslot to increase the level of the samples to be generated later.

4. A method as claimed in claim 1, **characterized** by setting limits for the level of the sample signal, and if the level of the sample signal is within the set limits, generating a calculated sample on the basis of the sample signal and the amplification coefficient used in automatic gain control, the calculated sample being used as the actual signal sample.

5. A method as claimed in claim 1, **characterized** by setting limits for the level of the sample signal, and if the level of the sample signal is within the set limits, multiplying the sample signal and the reciprocal of the amplification coefficient used in automatic gain control to generate a calculated sample to be used as the actual signal sample.

6. A method as claimed in claim 1, **characterized** by using the level of the signal sample generated at the start of the timeslot to decrease the levels of samples to be generated later, if the sample level exceeds a preset level.

7. A method as claimed in claim 1, **characterized** by adjusting the amplification used in automatic gain control on the basis of the level data of the samples generated at the start of the timeslot.

8. A method as claimed in claim 1, **characterized** by processing the generated signal samples, and as the levels of the signal samples are being adjusted, the adjustment is compensated for to eliminate the generation of signal samples with highly different levels.

9. A receiver (80) used in a TDMA radio system for receiving signals placed in timeslots, comprising amplifier means (20) for changing the level of a received signal by means of automatic gain control, and converter means (30) for taking samples of a signal placed in a timeslot, the converter means (30) using the samples to convert the signal into digital, **characterized** by

comprising control means (50) for adjusting the levels of the signal samples generated by the converter means (30) to optimal by means of automatic gain control

by the control means (50) using the levels of the signal samples generated at the start of the timeslot to adjust the levels of signal samples generated in the same timeslot later than the signal samples generated at the start of the timeslot.

10. A receiver as claimed in claim 9, **characterized** by the control means (50) using the samples generated at the start of a timeslot to adjust signal samples to be generated later in the same timeslot.

11. A receiver as claimed in claim 9, **characterized** by the control means (50) using the level of the signal sample generated first to adjust the levels of signal samples to be generated later in the same timeslot.

12. A receiver as claimed in claim 9, **characterized** by the control means (50) using the level of the signal sample generated at the start of the timeslot to increase the levels of samples to be generated later, if the level of the sample generated later is below a pre-set level.

13. A receiver as claimed in claim 9, **characterized** by the control means (50) setting limits for the level of the sample signal, and if the level of the sample signal is within the set limits, the control means (50) generate a calculated sample on the basis of the sample signal and the amplification coefficient used in automatic gain control, the calculated sample being used as the actual signal sample.

14. A receiver as claimed in claim 9, **characterized** by the control means (50) setting limits for the level of the sample signal, and if the level of the sample signal is within the set limits, the sample signal and the

reciprocal of the amplification coefficient used in automatic gain control are multiplied to generate a calculated sample to be used as the actual signal sample.

15. A receiver as claimed in claim 9, **characterized** by the control means (50) using the level of the signal sample generated at the start of the timeslot to decrease the levels of samples to be generated later, if the level of the sample generated later exceeds a pre-set level.

16. A receiver as claimed in claim 9, **characterized** by the control means (50) adjusting the amplification used in automatic gain control on the basis of the level data of the samples generated at the start of the timeslot.

17. A receiver as claimed in claim 9, **characterized** by the receiver (80) comprising processor means (40) for processing signal samples, and while the control means (50) adjust the levels of the signal samples, the control means (50) compensate for the effects of the amplification coefficients used in automatic gain control to eliminate the generation of signal samples with highly different levels.

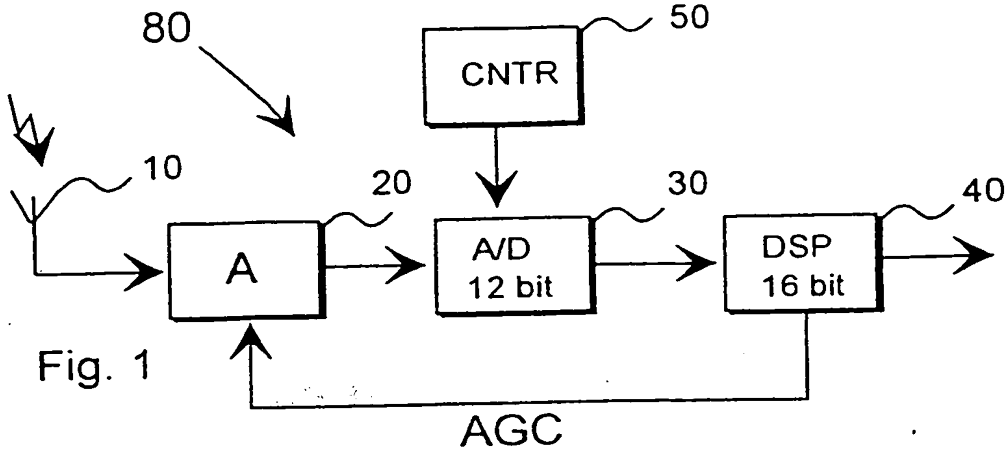


Fig. 1

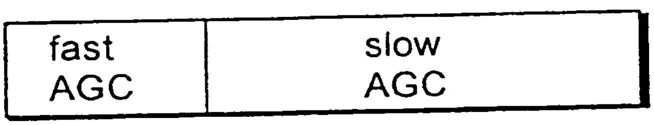


Fig. 3

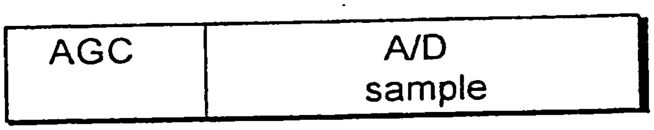


Fig. 4

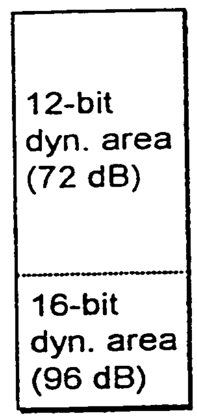


Fig. 2

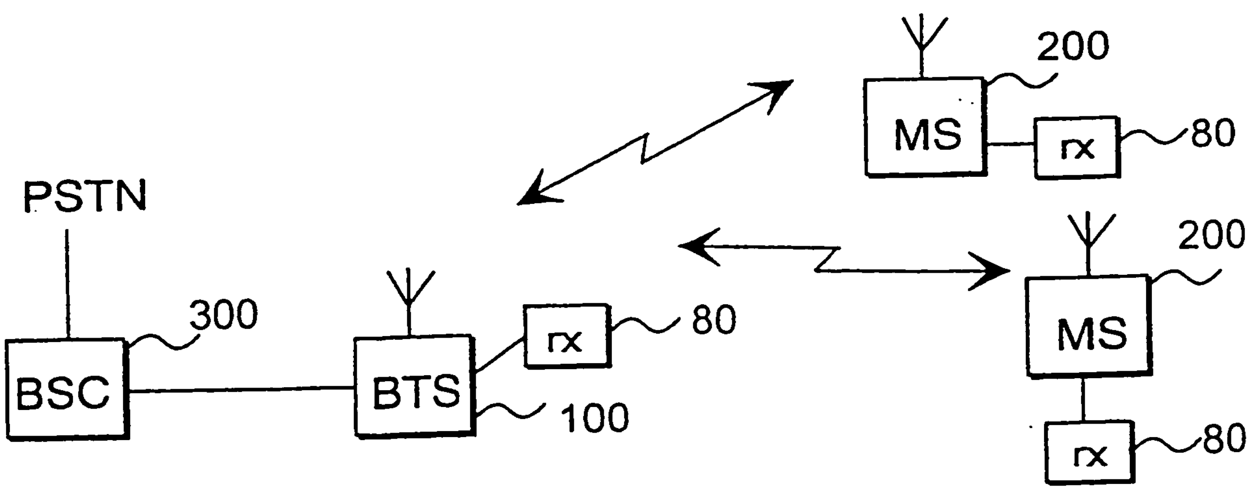
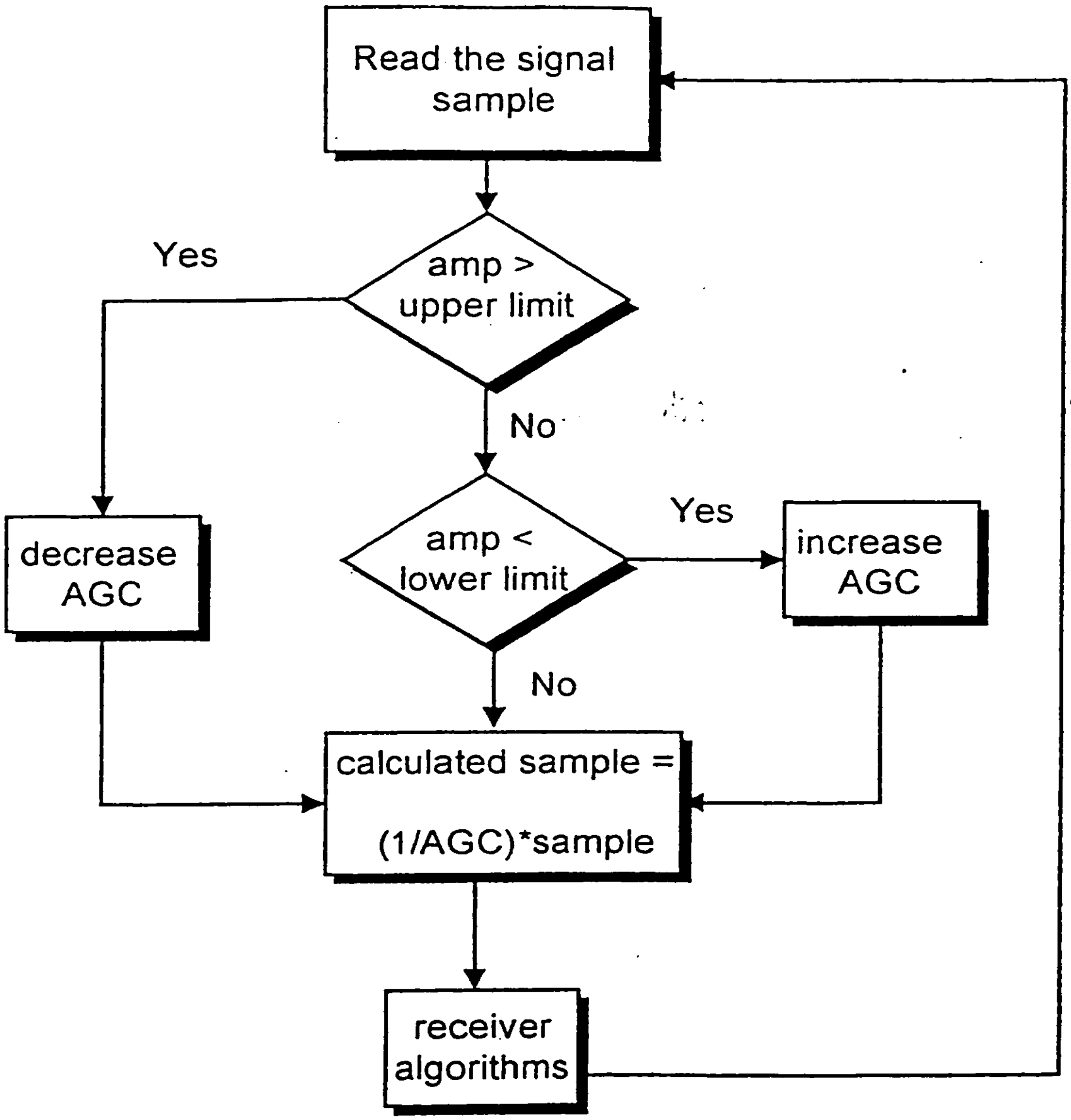


Fig. 6



Read the signal sample
amp > upper limit
Yes
No
decrease AGC
amp < lower limit
Yes
No
increase AGC
calculated sample =
(1/AGC)*sample
receiver algorithms

Fig. 5

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/01014

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H03G 3/20, H04B 7/00 // H03M 1/00

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WPIL, EDOC, INSPEC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 5493712 A (NALLEPILLI S. RAMESH ET AL), 20 February 1996 (20.02.96), column 1, line 50 - line 65; column 4, line 30 - column 6, line 5 --	1-3,6-7, 9-12,15,16
X	US 5184349 A (KENNETH B. RIORDAN), 2 February 1993 (02.02.93), abstract -- --------	1

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Date of the actual completion of the international search	Date of mailing of the international search report
5 May 1999	07-05-1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Eva Jedermark Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

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